Accordingly, departures may be made from such details without departing from the scope or spirit of applicant's general inventive concept.

WHAT IS CLAIMED IS:

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1. A method of making a powder metal rotor for a circumferential type interior permanent magnet machine, the method comprising:

filling a plurality of discrete first regions within an outer annular region of a disk-shaped die with a non-ferromagnetic powder metal so as to leave spaces between each discrete first region;

filling a plurality of discrete second regions in the outer annular region between the first regions with a soft ferromagnetic powder metal so as to maintain a radially inner circumferentially extending space between each discrete first region;

pressing the powders in the die to form a compacted powder metal disk;

sintering the compacted powder metal disk; and

providing permanent magnets in the radially inner circumferentially extending spaces between the discrete first regions of the outer annular region in an arrangement of alternating polarity to form a composite powder metal disk having a plurality of alternating polarity permanent magnets separated by magnetically non-conducting barrier segments and radially embedded by magnetically conducting segments.

2. The method of claim 1 further comprising filling an inner annular region of the die with a soft ferromagnetic powder metal to form the disk further having an inner annular magnetically conducting segment.

3. The method of claim 1, wherein all the regions are filled concurrently.

4. The method of claim 1, wherein all the regions are filled sequentially with the powder metal being pressed and sintered after each filling step.

5. The method of claim 1, wherein the providing of permanent magnets includes affixing prefabricated permanent magnets to the barrier segments.

6. The method of claim 1, wherein the providing of permanent magnets includes filling the radially inner circumferentially extending spaces with a hard ferromagnetic powder metal, pressing the hard ferromagnetic powder metal and sintering the pressed powder.

7. The method of claim 1, wherein the soft ferromagnetic powder metal is Ni, Fe, Co or an alloy thereof.

8. The method of claim 1, wherein the soft ferromagnetic powder metal is a high purity iron powder with a minor addition of phosphorus.

9. The method of claim 1, wherein the non-ferromagnetic powder metal is an austenitic stainless steel.

10. The method of claim 1, wherein the non-ferromagnetic powder metal is an AISI 8000 series steel.

11. The method of claim 1, wherein the pressing comprises uniaxially pressing the powders in the die.

12. The method of claim 1, wherein the pressing comprises pre-heating the powders and pre-heating the die.

13. The method of claim 1, wherein, after the pressing, the compacted powder metal disk is delubricated at a first temperature, followed by sintering at a second temperature greater than the first temperature.

14. The method of claim 1 further comprising filling the discrete second regions so as to further maintain a radially extending unfilled region through each discrete second region and filling the radially extending unfilled regions with a non-ferromagnetic powder metal, pressing the non-ferromagnetic powder metal, and sintering the pressed powder to form intermediate magnetically non-conducting bridge segments in the magnetically conducting segments.

15. A method of making a powder metal rotor for a circumferential type interior permanent magnet machine, the method comprising:

filling an inner annular region of a disk-shaped die with a soft ferromagnetic powder metal;

filling a plurality of discrete first regions within an outer annular region of the die with a non-ferromagnetic powder metal so as to leave spaces between each discrete first region;

filling a plurality of discrete second regions in the outer annular region between the first regions with a soft ferromagnetic powder metal so as to maintain a radially inner circumferentially extending space between each discrete first region;

pressing the powders in the die to form a compacted powder metal disk;

sintering the compacted powder metal disk; and

providing permanent magnets in the radially inner circumferentially extending spaces between the discrete first regions of the outer annular region in an arrangement of alternating polarity to form a composite powder metal disk having an inner annular magnetically conducting segment and an outer annular permanent magnet segment of a plurality of alternating polarity permanent magnets separated by magnetically non-conducting barrier segments and radially embedded by magnetically conducting segments.

16. The method of claim 15, wherein all the regions are filled concurrently.

17. The method of claim 15, wherein all the regions are filled sequentially with the powder metal being pressed and sintered after each filling step.

18. The method of claim 15, wherein the providing of permanent magnets includes affixing prefabricated permanent magnets to the inner segment.

19. The method of claim 15, wherein the providing of permanent magnets includes filling the radially inner circumferentially extending spaces with a hard ferromagnetic powder metal, pressing the hard ferromagnetic powder metal and sintering the pressed powder.

20. The method of claim 15, wherein the soft ferromagnetic powder metal is Ni, Fe, Co or an alloy thereof.

21. The method of claim 15, wherein the soft ferromagnetic powder metal is a high purity iron powder with a minor addition of phosphorus.

22. The method of claim 15, wherein the non-ferromagnetic powder metal is an austenitic stainless steel.

23. The method of claim 15, wherein the non-ferromagnetic powder metal is an AISI 8000 series steel.

24. The method of claim 15, wherein the pressing comprises uniaxially pressing the powders in the die.

25. The method of claim 15, wherein the pressing comprises pre-heating the powders and pre-heating the die.

26. The method of claim 15, wherein, after the pressing, the compacted powder metal disk is delubricated at a first temperature, followed by sintering at a second temperature greater than the first temperature.

27. The method of claim 15, wherein the sintering is performed in a vacuum furnace having a controlled atmosphere.

28. The method of claim 15, wherein the sintering is performed in a belt furnace having a controlled atmosphere.

29. The method of claim 15 further comprising filling the discrete second regions so as to further maintain a radially extending unfilled region through each discrete second region and filling the radially extending unfilled regions with a non-ferromagnetic powder metal, pressing the non-ferromagnetic powder metal, and sintering the pressed powder to form intermediate magnetically non-conducting bridge segments in the magnetically conducting segments of the outer annular permanent magnet segment.

30. The method of claim 15 further comprising filling a portion of the inner annular region in a desired pattern with a non-ferromagnetic powder metal, pressing the non-ferromagnetic powder metal, and sintering the pressed powder to form an inner magnetically non-conducting insert.

31. The method of claim 15 further comprising stacking a plurality of the composite powder metal disks axially along a shaft to form a powder metal rotor assembly.

32. A method of making a powder metal rotor for a circumferential type interior permanent magnet machine, the method comprising:

filling an inner annular region and a plurality of first portions of an outer annular region of a disk-shaped die with a soft ferromagnetic powder metal;

pressing and sintering the soft ferromagnetic powder metal in the die to form a compacted and sintered inner annular magnetically conducting segment and a plurality of compacted and sintered outer magnetically conducting segments;

filling a plurality of second portions in the outer annular region of the die with a non-ferromagnetic powder metal, the second portions being in alternating relation with the outer magnetically conducting segments;

optionally filling a plurality of third portions in the outer annular region of the die with a non-ferromagnetic powder metal, the third portions radially extending through an intermediate portion of each first portion;

pressing the non-ferromagnetic powder metal in the die to form a plurality of compacted magnetically non-conducting barrier segments and optional bridge segments;

sintering the compacted magnetically non-conducting barrier and optional bridge segments and the compacted and sintered inner annular and outer magnetically conducting segments; and

providing circumferentially extending permanent magnets in a plurality of radially inner fourth portions in the outer annular region between the magnetically non-conducting barrier segments in an arrangement of alternating polarity to form a composite powder metal disk having an inner annular magnetically conducting segment and an outer annular permanent magnet segment of a plurality of alternating polarity

permanent magnets separated by magnetically non-conducting barrier segments and radially embedded by magnetically conducting segments with optional intermediate magnetically non-conducting bridge segments.

33. The method of claim 32, wherein the providing step includes, after the second sintering step, filling the fourth portions with a hard ferromagnetic powder metal, pressing the hard ferromagnetic powder metal in the die to form a plurality of compacted permanent magnet segments, and sintering the compacted permanent magnet segments and the compacted and sintered inner annular and outer conducting segments and magnetically non-conducting barrier and optional bridge segments.

34. The method of claim 32 further comprising affixing prefabricated permanent magnets of alternating polarity in the fourth portions between the magnetically non-conducting barrier segments.

35. The method of claim 32, wherein the soft ferromagnetic powder metal is Ni, Fe, Co or an alloy thereof.

36. The method of claim 32, wherein the soft ferromagnetic powder metal is a high purity iron powder with a minor addition of phosphorus.

37. The method of claim 32, wherein the non-ferromagnetic powder metal is an austenitic stainless steel.

38. The method of claim 32, wherein the non-ferromagnetic powder metal is an AISI 8000 series steel.

39. The method of claim 32, wherein each pressing comprises uniaxially pressing the powder in the die.

40. The method of claim 32, wherein each pressing comprises pre-heating the powder and pre-heating the die.

41. The method of claim 32, wherein, after each pressing, the compacted segments are delubricated at a first temperature, followed by sintering at a second temperature greater than the first temperature.

42. The method of claim 32, wherein each sintering is performed in a vacuum furnace having a controlled atmosphere.

43. The method of claim 32, wherein each sintering is performed in a belt furnace having a controlled atmosphere.

44. The method of claim 32 further comprising stacking a plurality of the composite powder metal disks axially along a shaft to form a powder metal rotor assembly.

45. A powder metal disk for a rotor assembly in a circumferential type interior permanent magnet machine, the disk comprising alternating magnetically non-conducting barrier segments and embedded circumferentially extending permanent magnets, the permanent magnets alternating in polarity, and radially outer magnetically conducting segments embedding the permanent magnets, each having an optional intermediate magnetically non-conducting bridge segment extending radially from the permanent magnet to an outer circumferential surface of the disk, wherein the magnetically non-conducting barrier segments and optional bridge segments comprise pressed and sintered non-ferromagnetic powder metal and the outer magnetically conducting segments comprise pressed and sintered soft ferromagnetic powder metal.

46. The disk of claim 45 further comprising an inner annular magnetically conducting segment comprising pressed and sintered soft ferromagnetic powder metal adjacent a radially inner surface of each permanent magnet.

47. The disk of claim 45, wherein the soft ferromagnetic powder metal is Ni, Fe, Co or an alloy thereof.

48. The disk of claim 45, wherein the soft ferromagnetic powder metal is a high purity iron powder with a minor addition of phosphorus.

49. The disk of claim 45, wherein the non-ferromagnetic powder metal is an austenitic stainless steel.

50. The disk of claim 45, wherein the non-ferromagnetic powder metal is an AISI 8000 series steel.

51. The disk of claim 45, wherein the permanent magnets comprise pressed and sintered hard ferromagnetic powder metal.

52. The disk of claim 45, wherein the permanent magnets are prefabricated inserts affixed to the magnetically non-conducting barrier segments.

53. A powder metal disk for a rotor assembly in a circumferential type interior permanent magnet machine, the disk comprising:

an inner annular magnetically conducting segment; and

an outer annular permanent magnet segment comprising alternating magnetically non-conducting barrier segments and embedded circumferentially extending permanent magnets, the permanent magnets alternating in polarity, and radially outer magnetically conducting segments embedding the permanent magnets, each having an optional intermediate magnetically non-conducting bridge segment extending radially from the permanent magnet to an outer circumferential surface of the disk,

wherein the magnetically non-conducting barrier segments and optional bridge segments comprise pressed and sintered non-ferromagnetic powder metal and the inner annular and outer magnetically conducting segments comprise pressed and sintered soft ferromagnetic powder metal.

54. The disk of claim 53, wherein the soft ferromagnetic powder metal is Ni, Fe, Co or an alloy thereof.

55. The disk of claim 53, wherein the soft ferromagnetic powder metal is a high purity iron powder with a minor addition of phosphorus.

56. The disk of claim 53, wherein the non-ferromagnetic powder metal is an austenitic stainless steel.

57. The disk of claim 53, wherein the non-ferromagnetic powder metal is an AISI 8000 series steel.

58. The disk of claim 53, wherein the permanent magnets comprise pressed and sintered hard ferromagnetic powder metal.

59. The disk of claim 53, wherein the permanent magnets are prefabricated inserts affixed to the inner annular magnetically conducting segment.

60. The disk of claim 53, wherein the inner annular magnetically conducting segment further comprises a substantially star-shaped magnetically non-conducting insert of pressed and sintered non-ferromagnetic powder metal, with each tip portion of the star-shaped insert extending toward a respective permanent magnet in the outer annular permanent magnet segment.

61. The disk of claim 53 further comprising an inner annular magnetically non-conducting segment of pressed and sintered non-ferromagnetic powder metal radially inward of the inner annular magnetically conducting segment.

62. A powder metal rotor assembly for a circumferential type interior permanent magnet machine, comprising:

a shaft; and

a plurality of composite powder metal disks axially stacked along and bonded to the shaft, each disk comprising:

(a) an inner annular magnetically conducting segment; and

(b) an outer annular permanent magnet segment comprising alternating magnetically non-conducting barrier segments and embedded circumferentially extending permanent magnets, the permanent magnets alternating in polarity, and radially outer magnetically conducting segments embedding the permanent magnets, each having an intermediate magnetically non-conducting bridge segment extending radially from the permanent magnet to an outer circumferential surface of the disk,

wherein the magnetically non-conducting barrier segments and bridge segments comprise pressed and sintered non-ferromagnetic powder metal and the inner annular and outer magnetically conducting segments comprise pressed and sintered soft ferromagnetic powder metal.

63. The assembly of claim 62, wherein the soft ferromagnetic powder metal is Ni, Fe, Co or an alloy thereof.

64. The assembly of claim 62, wherein the soft ferromagnetic powder metal is a high purity iron powder with a minor addition of phosphorus.

65. The assembly of claim 62, wherein the non-ferromagnetic powder metal is an austenitic stainless steel.

66. The assembly of claim 62, wherein the non-ferromagnetic powder metal is an AISI 8000 series steel.

67. The assembly of claim 62, wherein the permanent magnets comprise pressed and sintered hard ferromagnetic powder metal.

68. The assembly of claim 62, wherein the permanent magnets are prefabricated inserts affixed to the inner annular magnetically conducting segment. The assembly of claim 62, wherein the inner annular magnetically conducting segment further comprises a substantially star-shaped magnetically non-conducting insert of pressed and sintered non-ferromagnetic powder metal, with each tip portion of the star-shaped insert extending toward a respective permanent magnet in the outer annular permanent magnet segment.

69. The assembly of claim 62 further comprising an inner annular magnetically non-conducting insert of pressed and sintered non-ferromagnetic powder metal radially inward of the inner annular magnetically conducting segment.

70. The assembly of claim 62 further comprising an inner annular magnetically non-conducting insert of pressed and sintered non-ferromagnetic powder metal radially inward of the inner annular magnetically conducting segment.